A CONTRIBUTION TO THE LIFE HISTORY OF THE PUFFER, *SPHEROIDES MACULATUS* (SCHNEIDER) [1]

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Introduction.

The present paper embodies the results of studies on *Spheroides maculatus* (Schneider), carried out at Atlantic City, New Jersey, chiefly during the month of August, 1920, where a temporary field laboratory was established on Young's Million Dollar Pier through the courtesy of Captain E. L. Young. All material for study was obtained from the two pound-nets operated upon this pier.

The temperature of the water during this season was abnormally low, being comparable to that normally encountered below the five fathom line in this region. Although conditions in general were rather unsatisfactory for this type of work, no difficulty was encountered in securing adequate material for the study of this species.

The drawings of the eggs and larvae were made from living material by means of the camera lucida. In most cases a small quantity of chlorotone was added to the sea water containing the larvae, to quiet them. All illustrations, excepting Fig. 87 have been executed by the junior author.

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[1] Published by permission of the United States Commissioner of Fisheries.

Ontogeny.

Spawning.—Ripe females of this species were taken from July 30 to August 27, which were the first and last dates on which specimens were examined. There seemed to be no increase or decrease in the proportionate number of ripe fish, which fact suggests that the peak of their sexual activity extends well over the period in this region. Hard and spent individuals were constantly taken with the ripe ones. The ova passed freely on the application of very slight pressure, issuing forth in a stream about 3 mm. in diameter. Ripe males were frequently taken, but equal success in fertilization was obtained by macerating the testes of fish from which milt would not flow. The sexes were present in approximately equal numbers.

Eggs.—The eggs are transparent, spherical, and invested with a smooth adhesive covering which is irregular in outline. They are demersal and readily become attached to any submerged object, or caked in a mass, owing to their adhesive nature. Where numbers adhere to a side of the container, close together and in a single layer, the adhesive envelope assumes a somewhat hexagonal appearance. The surfaces of the eggs are finely reticulated, rather resembling crepe paper. The eggs average about 0.874 mm. in diameter, varying from .85 to .91 mm., while the enveloping adhesive coat increases the diameter to an average of about .954 mm. A large number of colorless oil globules of low refractive index are present in a foamy cluster, which averages about .34 mm. in diameter, and a very faint yellowish olive tinge can be detected in the area in which the blastoderm is to develop. Fig. 81, A represents the unfertilized egg.

Embryology.—The eggs, of which the development was studied, were incubated in small bowls, with a daily change of water, at a temperature which averaged about 67°F. At fifteen minutes after fertilization no great change was apparent, but within the following two hours the first cleavage had been completed (Fig. 81, B), and by sixteen hours after fertilization the blastodisc had commenced to indicate the approaching differentiation (Fig. 81, C). By twenty-four hours the embryo was quite

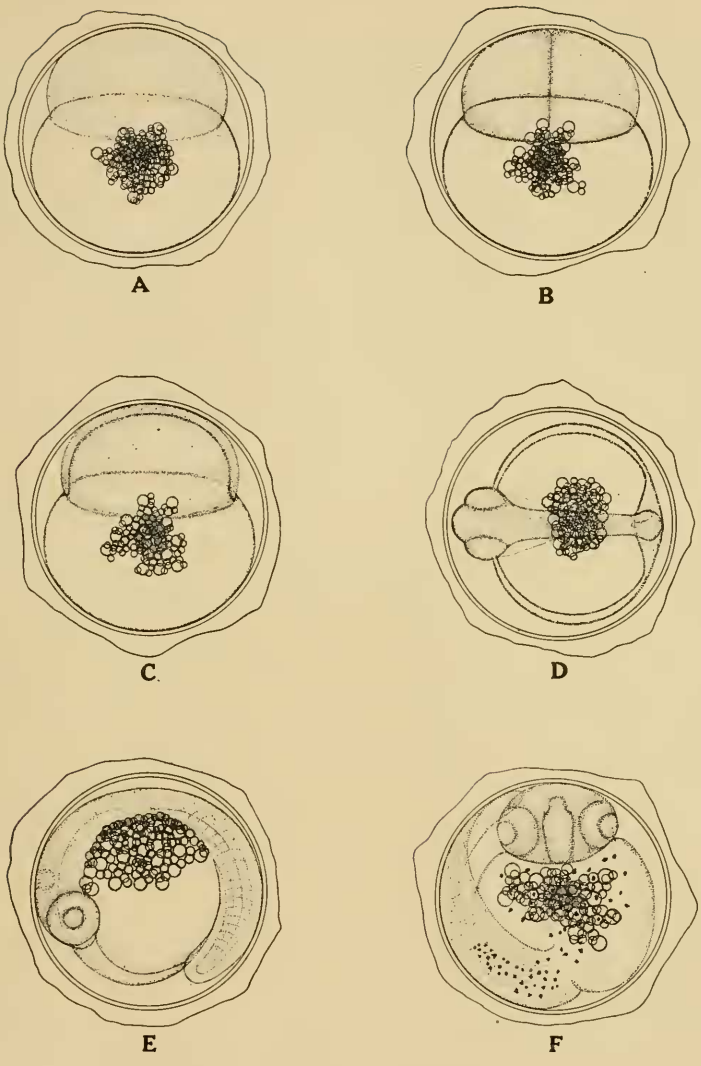

FIG. 81. MAGNIFICATION 36 X.

A—Unfertilized egg. B—Egg with blastoderm of two cells. Two and one-half hours after fertilization. C—Egg showing early stage in the differentiation of the embryo. Sixteen and one-half hours after fertilization. D—Egg showing a moderately advanced stage of differentiation of the embryo. Forty hours after fertilization. E—Egg with moderately advanced embryo. Seventy hours after fertilization. F—Egg with advanced embryo. Ninety hours after fertilization.

distinct and in the succeeding twenty it had reached more than half way around the yolk (Fig. 81, D) At seventy hours the tail was free at its tip, vertebral somites were visible, and convulsive squirmings had commenced. Scattered black chromatophores had appeared along each side and the eyes were quite distinct. The oil globules were chiefly located in the dorsal half of the yolk (Fig. 81, E). At ninety hours, in addition to the black chromatophores, red and orange ones were scattered along the sides. The anterior ventral surface of the yolk was well covered with large black chromatophores, rather dendritic, and there was a suggestion of the oil globules consolidating into a somewhat lesser number of larger spheres. A few small black chromatophores and punctulations were located in the posterior part of the iris and on the tip of the snout (Fig. 81, F). At this stage the tip of the tail overlapped the head and the embryo exhibited much activity. The eggs began hatching at about one-hundred and twelve hours after fertilization. At this time they were steadily increasing in pigment content. The pigmentation terminated posteriorly in abrupt fashion about midway between the vent and the tip of the tail, and at this point a brilliant opaque chrome yellow spot was apparent on the dorsal surface. Numbers hatched however before the chrome yellow spot appeared (Fig. 82). Most of the larvae emerged from the egg tail first, although in a few cases the head came first. Both the eggs and larvae were decidedly variable during the entire period they were under observation, especially in the matter of pigmentation.

The frontispiece (Fig. 80) represents the typical coloration of the fry at the age of five days. Various shadings have been used in the text figures in an attempt to represent the very striking coloration exhibited by this species. Red has been represented by large closely placed dots, yellow by small ones, and the various green, orange, and purple markings by short lines, the location of each being explained in the text. By comparing the line drawings with the colored plate, a fair idea of the pigmentation at each stage may be gained, since, while the amounts of pigment present in the various stages differ, the actual colors shown by the chromatophores differ little from those represented in the plate.

Larval development.—The newly hatched larvae averaged about 2.41 mm. in length. The yolk sac was small and still contained oil globules. The head was somewhat deflected and the eyes, the pupils of which were not yet dark, were directed a trifle forward and downward. The pectoral fins were difficult to see, owing to the heavy pigment lying beneath them. The coloration was brilliant; red, orange, yellow and black chromatophores being thickly distributed over the body. Deep purplish black chromatophores invested the anterior end of the yolk sac and some were scattered through the iris, which also contained a cluster of heavy black ones in the dorsal and posterior quadrant. Numerous minute tubercles were present over practically the entire body. The newly hatched larvae were very active and possessed considerable vitality. Fig. 88 shows a detailed profile of the head at this age.

As development advanced the red pigment became relatively reduced, the orange and yellow coming more into prominence. About twenty-four hours after hatching the pupil became black, the nostrils were plainly visible, the pectorals more distinct, and what seemed to be beginnings of lateral line organs had appeared. Seven pairs of these organs were observed in a two day old specimen, and probably more were present but not distinguishable from the surrounding tissue. Three pairs have their origin over the eyes, a small and a large pair are posterior to the pectorals and another small pair over the vent, as well as a pair somewhat forward of that point (Fig. 83). On treating one specimen with chlorotone a secretion appeared to exude from these bodies, which indicated their glandular nature. Fig. 89 shows in detail the vent and location of the two posterior glands, and Fig. 90 represents the appearance, in profile, of the large one just behind the left pectoral in a specimen seven days old.

At two days the vent and mouth were open, and in addition to the other pigments, various green markings had appeared, especially in the iris. The yolk was materially reduced and at three days the mouth was functioning. Viewed by reflected light the colors were brilliant and metallic. The fry were active and decidedly heliotropic. The chrome yellow caudal spot, pre-

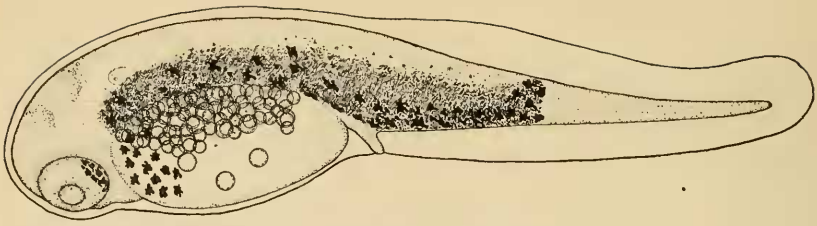

FIG. 82. NEWLY HATCHED FISH.
Actual length, 2.41 mm.

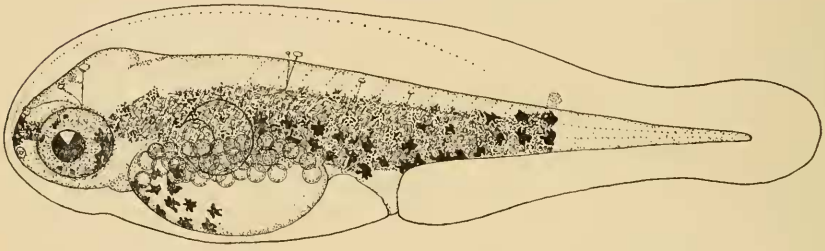

FIG. 83. LARVAL FISH ONE DAY AFTER HATCHING.
Actual length, 2.50 mm.

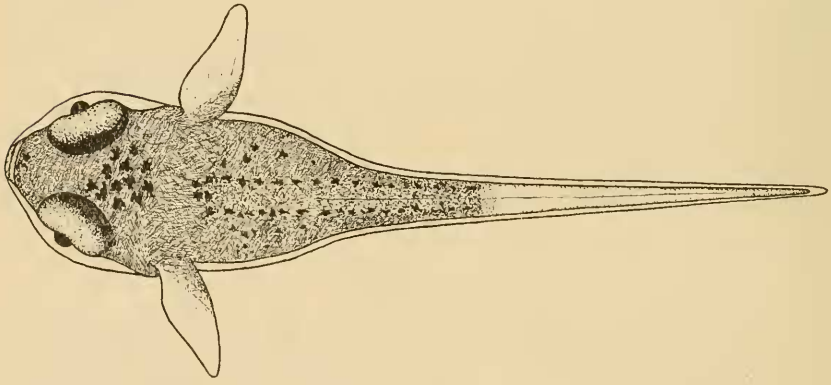

FIG. 84. LARVAL FISH FIVE DAYS AFTER HATCHING.
Actual length, 2.55 mm.

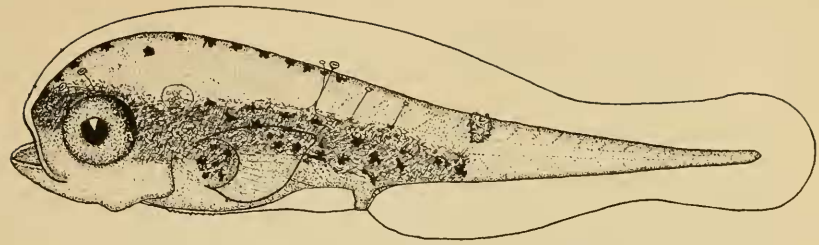

FIG. 85. LARVAL FISH SEVEN DAYS AFTER HATCHING.
Actual length, 2.62 mm.

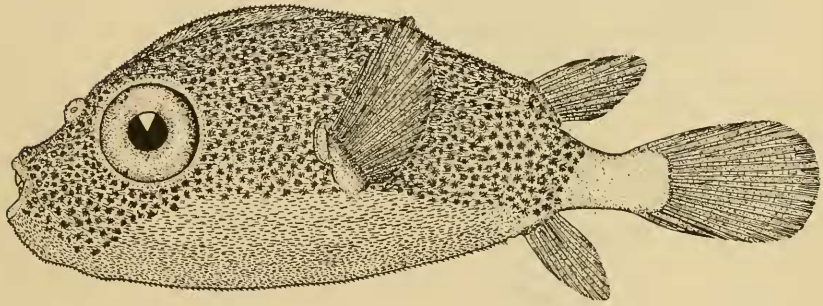

FIG. 86. POST LARVAL FISH.
Actual length, 7.35 mm.

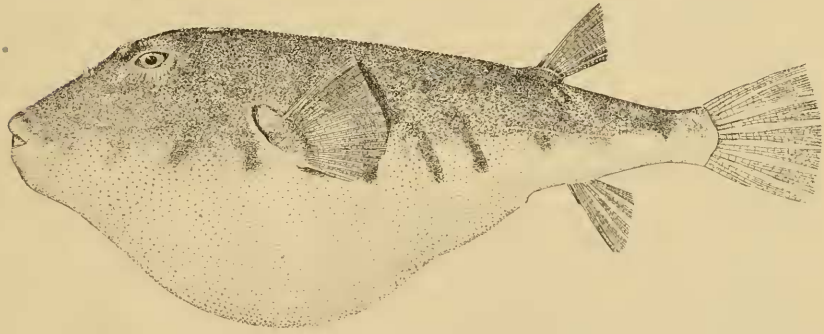

FIG. 87. ADULT FISH, PARTLY INFLATED.
Actual length, 200 mm.

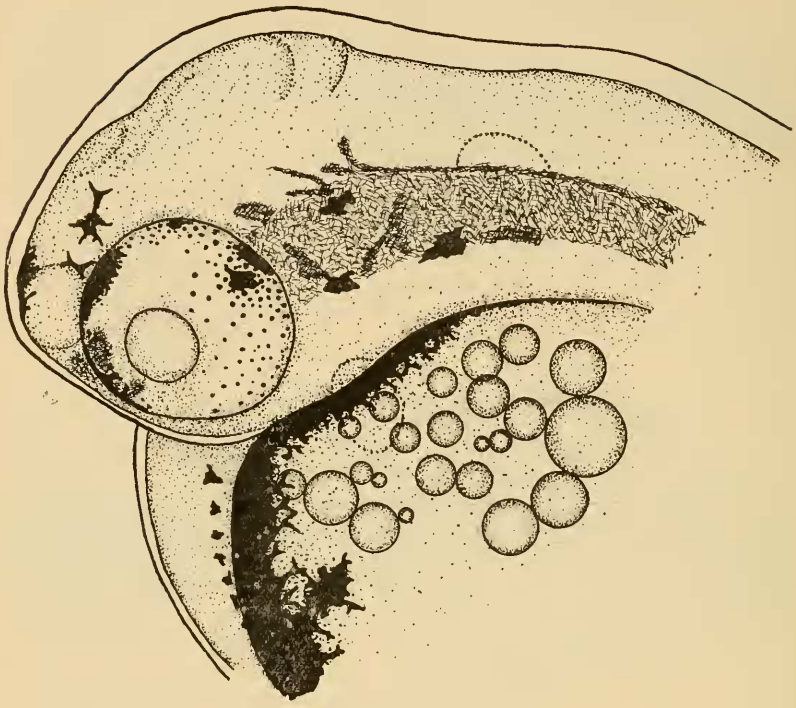

FIG. 88. DETAIL OF HEAD OF NEWLY HATCHED LARVA.
Actual length of entire fish nearly 2.40 mm.

viously noted, and a few black ones on the head constituted the only dorsal pigments.

On the fifth day numerous tubercles of considerable size were observed on the ventral surface. The eyes were coming into a more nearly lateral position and a small spine was developing on the operculum. The black chromatophores on the abdominal region (the yolk being practically absorbed and the oil globules gone) were decidedly dendritic. The pectoral was assuming a less spatulate shape, a rather pronounced point appearing near the upper margin, and the maxillary was well formed and prominent (Fig. 84). The tip of the tail, shown by Fig. 91, indicates the tuberculated appearance of the body in a six day old specimen. At this age the otoliths were becoming

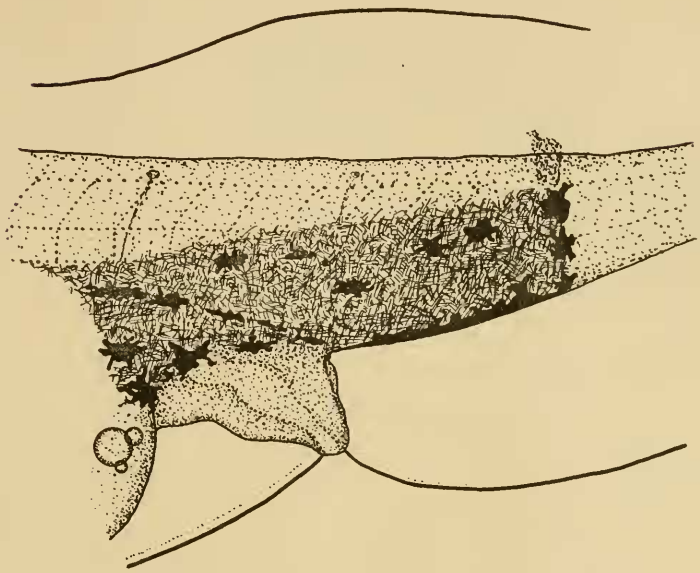

FIG. 89. DETAIL OF VENT OF TWO DAY OLD LARVA.
Actual length of entire fish nearly 2.52 mm.

more complicated in conformation and the body was becoming opaque. At seven days, (Fig. 85), little further change in appearance could be observed. The tubercles, especially on the ventral surface steadily increased in size, and the maceration of some from that location disclosed small barbed hooks as shown in Fig. 92. At ten days the larvae were all dead or dying, the largest having reached a length of 2.65 mm.

It is believed that these eggs and larvae would prove exceptionally satisfactory for detailed studies of embryology and larval development; the eggs, because of extreme hardihood, transparency, and possession of an adhesive coat maintaining them in a definite position; and the larvae because of the large and varied chromatophores that develop so strikingly, and their great tenacity to life.

Fig. 86 was drawn from a specimen 7.35 mm. long taken by the U. S. S. Grampus July 31, 1913, station No. 10081, over a depth of eleven fathoms off the New Jersey coast near Barnegat, the net haul being from ten fathoms to the surface. At this stage most of the diagnostic characters of the adult have been

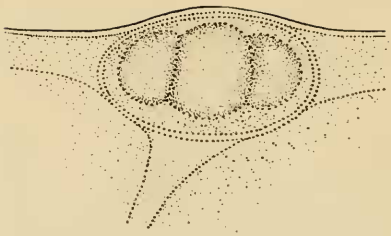

FIG. 90. PROFILE OF LATERAL ORGAN, POSTERIOR OF LEFT PECTORAL FIN, FROM A SEVEN DAY OLD LARVA.
Magnification nearly 360 X.

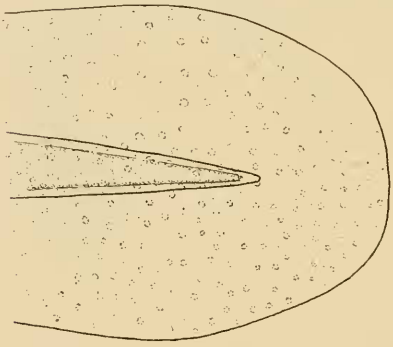

FIG. 91. TIP OF TAIL OF SIX DAY OLD LARVA SHOWING TUBERCLES.
Magnification nearly 104 X.

FIG. 92. SPINES FROM VENTRAL SURFACE OF TEN DAY OLD LARVA.
Magnification nearly 360 X.

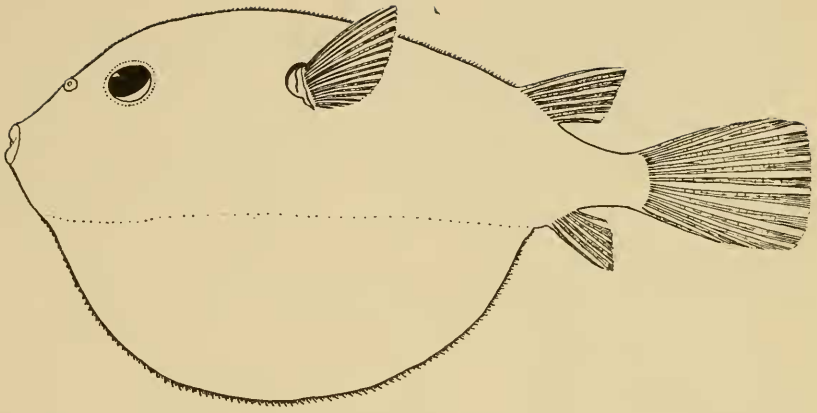

FIG. 93. OUTLINE OF A SPECIMEN 22.5 MM. LONG, SHOWING PROPORTIONS ASSUMED ON INFLATION BY THE POST LARVAL FISH.

From United States National Museum collection. Aug. 11, 1892, Quissett Harbor, Mass.

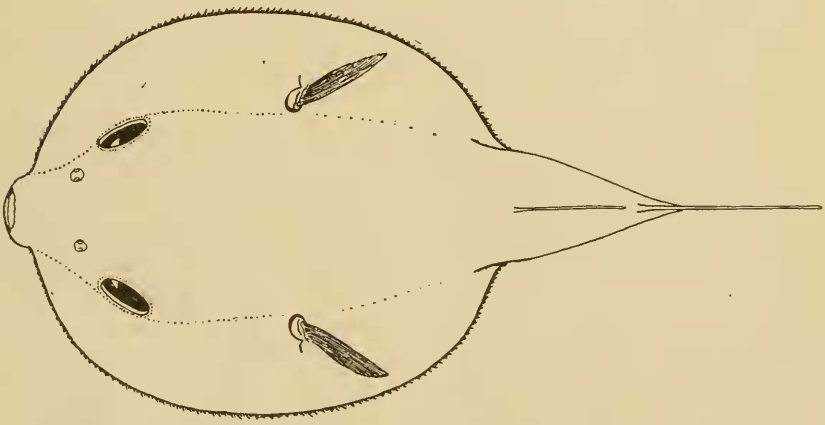

FIG. 94. DORSAL VIEW OF SPECIMEN SHOWN IN FIGURE 93.

acquired, although the skin surrounding the body is more distensible than in the mature fish. The transparent membranes covering the eyes move away from them on inflation, adding to the grotesqueness of appearance. The skin is literally turned inside out over the caudal, dorsal and anal fins, the fish inflating to such an extent that these fins are buried in furrows in the distended skin. In preserved specimens the dorsal outline over the eye is extended by a fold of this expansive membrane, which shows in the deflated specimen illustrated by Fig. 86. The projecting pectorals are practically the only prominences of note on the otherwise spherical surface of an inflated specimen. As shown in Figs. 93 and 94, by the time the species attains a length of 22.5 mm. their inflatibility does not exceed that of the adults. The entire skin, however, is still loose, and upon inflation, as the drawing indicates, the membrane covering the eye becomes pulled down to a certain extent.

Latham, 1916[2], reports having seen specimens 2.5 to 7.5 cm. at Orient, Long Island, during November and the early part of December. It may be inferred that the smaller ones at least must have been hatched that same year, when it is considered that specimens of over 7 mm. were taken in July by the Grampus. This, together with the fact that specimens in graduated sizes from a few mm. in length to adult size have been taken at most diverse seasons, indicates a long spawning season.

Preserved material.—Examples of all stages studied were preserved in strong formalin. The most notable change in the younger eggs was the change of the oil globules to a decidedly amber color, and their migration from the interior of the yolk to its outside wall, at which surface they mostly adhered. The blastodisc and the early embryos became white and opaque. All chromatophores lost their color and were difficult to differentiate, excepting the black ones. The prominent chrome yellow spot nearly disappeared, and the lateral glands were almost indistinguishable. Staining with alizerin red failed to aid much in bringing out these details.

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[2] Latham, Roy—Migration notes of fishes from Orient, Long Island. Copeia, March 24, 1916, No. 41, p. 22.

Food.

The stomachs of 102 specimens taken between July 30 and August 4 were examined immediately on capture. The range of total lengths was from 14 to 24 cm. Some individuals were spawned out, others still hard, although the majority were ripe. No variation in diet could be correlated with size, sex or condition. The males were fifty-nine in number and the females forty-three.

The accompanying table indicates the number of stomachs containing each constituent of their food.

Material	Number of stomachs.
Small crabs	14
Unidentified crustaceans	2
Mussels	7
Univalves	1
Unidentified	82
Empty	16

The crabs were all of small non-commercial species. The unidentified material consisted largely of matter reduced to an offensive blue or yellowish paste. The apparent discrepancy in numbers is accounted for by the fact that some specimens partook of more than one kind of food.

Linton, 1905[3], found on examining fifteen specimens during July and August at Beaufort, N. C., that their food included fragments of oysters, scallops, mussels, razor-clams, gasteropods, barnacles, crabs, shrimp, sea-urchins, worms, ascidians, bryozoans, and watermelon seed, which gives the species a much more varied diet than found in the present investigation.

Relative Size of the Sexes.

The females of this species average somewhat larger than the males. Inspection of Fig. 95 shows that there is a difference of 3 cm. between the modal lengths of the two sexes. The

[3] Linton, Edwin.—Parasites of the fishes of Beaufort, N. C. In Bulletin, U. S. Bureau of Fisheries, Vol. XXIV, 1904, p. 402.

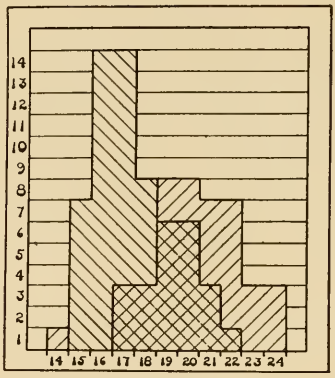

FIG. 95.

Horizontal index—Total lengths in centimeters. Vertical index—Number of individuals. Males represented by hatching from upper left to lower right corner. Females represented by hatching from upper right to lower left corner.

difference of the averages is slightly less, being about 2.85 cm. The 102 specimens examined for food determination were measured for plotting this graph. It is evident that fish more than 22 cm. long are almost surely females, while those less than 17 cm. are nearly all males. The sole female of 14 cm. length was probably a large specimen of a younger group, the remainder of which probably passed through the meshes of the net or were chiefly located in another area.

This knowledge proved very useful when dissecting the fish for eggs and milt, as by simply selecting the largest and smallest examples of a catch, both sexes could be had with almost entire certainty.

While both gonads were functioning in ripe fish, in all cases the left one was considerably larger than the right.

The Relation of Length to Weight.

The total lengths and weights of the 102 specimens of both sexes formed the basis of Fig. 96 which is arranged to show the weight of a fish of any given length or vice versa. These are plotted against each other, the larger circles indicating the points obtained by averaging the weights of all specimens in their respective length groups, which are in steps of 1 cm. The small circles on either side of the large ones indicate the high-

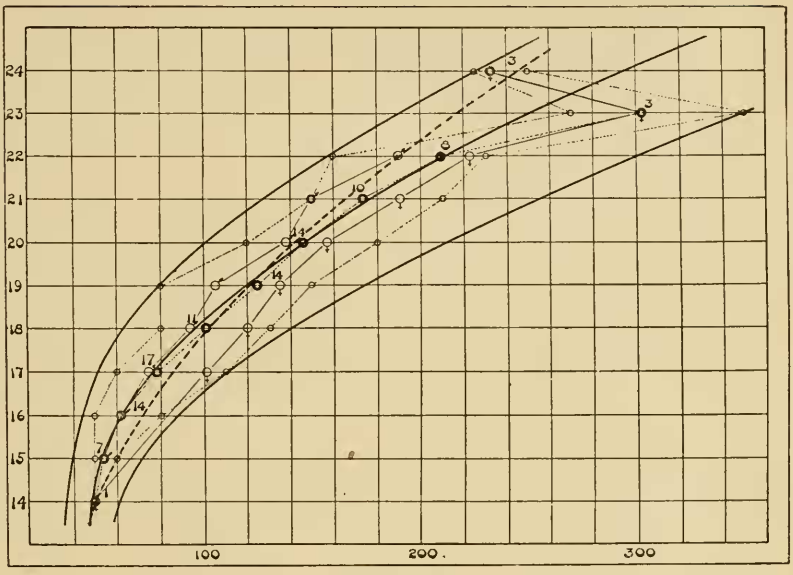

FIG. 96.

Horizontal index—Weights in grams. Vertical index—Total lengths in centimeters. Large circles—Average weight of corresponding length group. Small circles—Extremes in weight for corresponding length group. Numbers near large circles—Number of specimens making up average. Sex symbols—Average weight of sex indicated for corresponding length group. Center heavy curve—Line of average weights, smoothed. Outer heavy curves—Lines of extreme variation of weights. Heavy dashed curve—Line of formula, $w=l^3/56$.

est and lowest weights found in the individual groups. The central heavy curved line is the theoretical curve obtained by smoothing the dotted line connecting the large circles. It graphically represents the change in relation of length and weight as growth increases. The two outer heavy curved lines represent the limit of individual variation as established by the plotted points. The sex symbols connected by light solid lines shows the average weight for the indicated sex in each length group. This shows well the fact that males weigh considerably less than females of a given length. The modal weight of the males is about eighty-two grams less than that of the females, while the difference of the average weights is about eighty-seven grams.

It is evident that having the length or weight of a fish of this species, the other may be had by inspection of the curve,

the central lines giving the probable measurement, while the outer two limit the known variation in the breeding season. If the specimen in question is a male its weight will in all probability fall between the central line and the left hand outer one, while if it is a female it will probably be located on the other side of the central line.

On the assumption that the weights of fish of this species vary as the cube of their length multiplied by some constant, as is usual in fishes, the formula $w = l^3/56$ was calculated in which $w =$ weight in grams, $l =$ length in cm., and $56 =$ the constant. The heavy dashed curve was plotted from this equation. While it does not follow the smoothed curve perfectly it keeps well within the limitations required and the small discrepancies can be accounted for by the fact that the specimens weighed varied in sex, development of the gonads, and amount of material present in the alimentary tract.

Summary.

1. *Spheroides maculatus* has a long spawning season, probably lasting all through the warmer months.

2. Artificial fertilization is readily accomplished and owing to the transparency, adhesive nature, and hardihood of the ova, as well as the vitality of the larvae, the species is ideally suited for studies of early development.

3. Incubation occupies about three days and ten hours at an average temperature of 67°F.

4. The critical period for the larvae of this species appears to be on or about the tenth day after hatching.

5. Preservation in formulin destroys the finer details but fails to make the eggs or larvae unidentifiable.

6. The food of *Spheroides* does not include organisms of any considerable commercial value.

7. The females average larger than the males.

8. In specimens of equal length the females are somewhat heavier than the males, at least in the breeding season, although this is irrespective of the condition of the gonads.

9. The relation of length to weight in this species is approximated by the formula $w = l^3/56$.